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SMALL MAMMAL CENSUS AND CONTROL ON A HARDWOOD PLANTATION

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ABSTRACT: For centuries, Man has been at conflict with and has suffered untold crop losses to ubiquitous small mammals. Such losses may range from unnoticed removal of vegetation in hay and grain fields to 95 - 99 percent losses in unprotected orchards or forest plantations. A most dramatic and conspicuous type of damage occurs where large numbers of meadow voles cause excessive tree girdling damage to a wide variety of plantation grown trees.

Surveys of small mammal populations carried out on a hardwood plantation in southern Ontario during 1971-72-73 indicated the magnitude of the rodent problem. Control measures using broadcasting of anticoagulant-treated grain proved extremely effective but of temporary duration. Rapid reinvasion and high rate of reproduction soon brought the population number to former levels or higher. A poisoned bait feeder station developed and field tested by the writer proved extremely effective in providing an inexpensive long-term means of rodent control on the study area.

Throughout recorded history man has suffered untold losses to ubiquitous harmful small mammals and, largely through default, apathy, and ignorance, continues to do so. Losses of major proportions have been noted in forest plantations, commercial orchards, vegetable, grain and hay crops. Losses as high as 95 to 99 percent of plantation grown trees have been recorded by Moore (1940), Eadie (1954), the National Academy of Sciences (1970), von Althen (1971), Pank and Matschke (1972). In many instances young trees had been girdled and killed by meadow voles.

I became involved in such a rodent problem study when in 1971 the western region of the Canadian Wildlife Service at Edmonton, Alberta, was requested to assess the populations of small mammals on the Coulson Tract - an area of abandoned farmland near Toronto, Ontario (Figure 1.), on which attempts had been made during the previous 15 years to establish a hardwood plantation. Willed to the Ontario Department of Lands and Forests with the stipulation the land be forested, the area was planted in 1958 with white ash (Fraxinus americana L.) and basswood (Tilia americana L.) seedlings. Within a year many of the seedlings were either girdled by mice, browsed by rabbits, or smothered by weeds. In 1959 the area was replanted to white pine (Pinus strobus L.) and white spruce (Picea glauca (Moench) Voss). From 1960 to 1965, dead trees were replaced each spring and the weeds cut using a rotary mower. Despite the fact that two pounds of Phosbait rodenticide-treated grain were applied per acre on the area during most years, yet the small mammal population continued to persist in seemingly large numbers. No formal assessment of their numbers was made, however, by management personnel either before or after the control measures were carried out. Tree losses from girdling damage was particularly severe during the winter of 1967-68.

Examination of the Coulson Tract indicated by late August a lush crop of weeds and grasses covered much of the plantation and provided a most suitable habitat for a large population of small mammals. Waist to shoulder high wild carrot (Daucus carota L.), Canada thistle (Circium arvense L. Scop.), wild aster (Aster spp.) and goldenrod (Solidago spp.) combined with abundant grasses -- quackgrass (Agropyron repens L. Beauv.), chess (Bromus tectorum L.), and timothy (Phleum pratense L.) dominated much of the area and provided food and shelter for numerous small mammals.

A trapping grid to accomodate 300 live traps on a 40 foot by 30 foot spacing was established on 8.3 acres of the Coulson Tract in September, 1971. As shown in Figure 2, this grid formed a portion of a 20 acre sector of the plantation. A single Sherman-type live trap was set within a 5-foot radius of each trapping stake. The traps were baited with a paste mixture of ground beef suet, raisins, walnuts, peanut butter, oatmeal and oil of aniseed. In addition a thin slice of apple placed in each trap served as a moisture supplement for captured animals. A small handful of terylene fiberfill placed in each trap provided nest material. A rectangular piece of plywood was placed over each trap to prevent direct exposure of the trap to the hot sun or excessive chilling at night, thereby reducing losses in captured small mammals. All traps were baited at the beginning and on the fifth day of a ten day trapping period. All traps were checked twice daily. The small mammals taken in the traps were identified as to species, sex, age group, location and date of capture. Mice and short-tailed shrews were marked by using numbered fingerling tags applied to the ears prior to release at the point of capture; numbered ring tags were used to identify cinereus shrews.

Figure 1. Location of small mammal study area near Toronto, Ontario.

Following the initial 10-day trapping period all traps were closed and two pounds of grain, treated with the anticoagulant rodenticide Rozol, were broadcast per acre on the 20 acre study area. A second 10-days of live trapping to assess the effectiveness of the rodenticide commenced five days after the application. When no reduction in the numbers of animals being captured each day was noted by midway through the second trapping period, another application of treated grain was applied to the area.

A total of 281 small mammals were handled in 623 captures and recaptures on the trapping grid during this initial study. Of the animals trapped, 78.3 percent were meadow voles (Microtus pennsylvanicus), 10.3 percent cinereus shrews (Sorex cinercus), 6.4 percent deer mice (Peromyscus maniculatus), and 5.0 percent short-tailed shrews (Blarina brevicauda).

The number of new animals taken alive and dead during each check of the traps, the number of recaptures, alive and dead, the accumulating number of animals tagged and hence available for recapture, and the ratio of recaptures in the total daily catch were parameters used in calculating the theoretical small mammal population (following Hayne, 1949) and fiducial limits (95% probability) present on the area. The calculations indicated a population of 32.4 animals per acre. The mean home range of 55 Microtus captured four or more times was 7,505 square feet or slightly over 1/6 acre.

Application of the anticoagulant rodenticide in our initial field trial was not successful due in part to an inadequate concentration of the active ingredient applied to the grain bait, an inadequate rate of application of the treated grain in the field, and in our not allowing a sufficiently long feeding time between the date of application and the commencement of the second assessment trapping period.

A reassessment of small mammal populations on the Coulson Tract carried out in late May 1972 indicated the presence of 16.1 small mammals per acre. Of these 94.9 percent were meadow voles. Rozol-treated oat groats were again broadcast over the study area, this time at a rate of 15 pounds per acre. Following a 10-day feeding period, the grid area was trapped for a second 10-day period to assess the effectiveness of the poisoning program. In this evaluation period, not one of the 98 animals tagged earlier were caught again. In ten days of live trapping, only ten new small mammals were captured (7 Microtus and 3 Peromyscus).

It is assumed the entire small mammal population had been wiped out by the broadcast poisoned bait and the new animals taken were invaders from the surrounding fields. Only 3.3 animals per acre existed on the study area following this poisoning program.

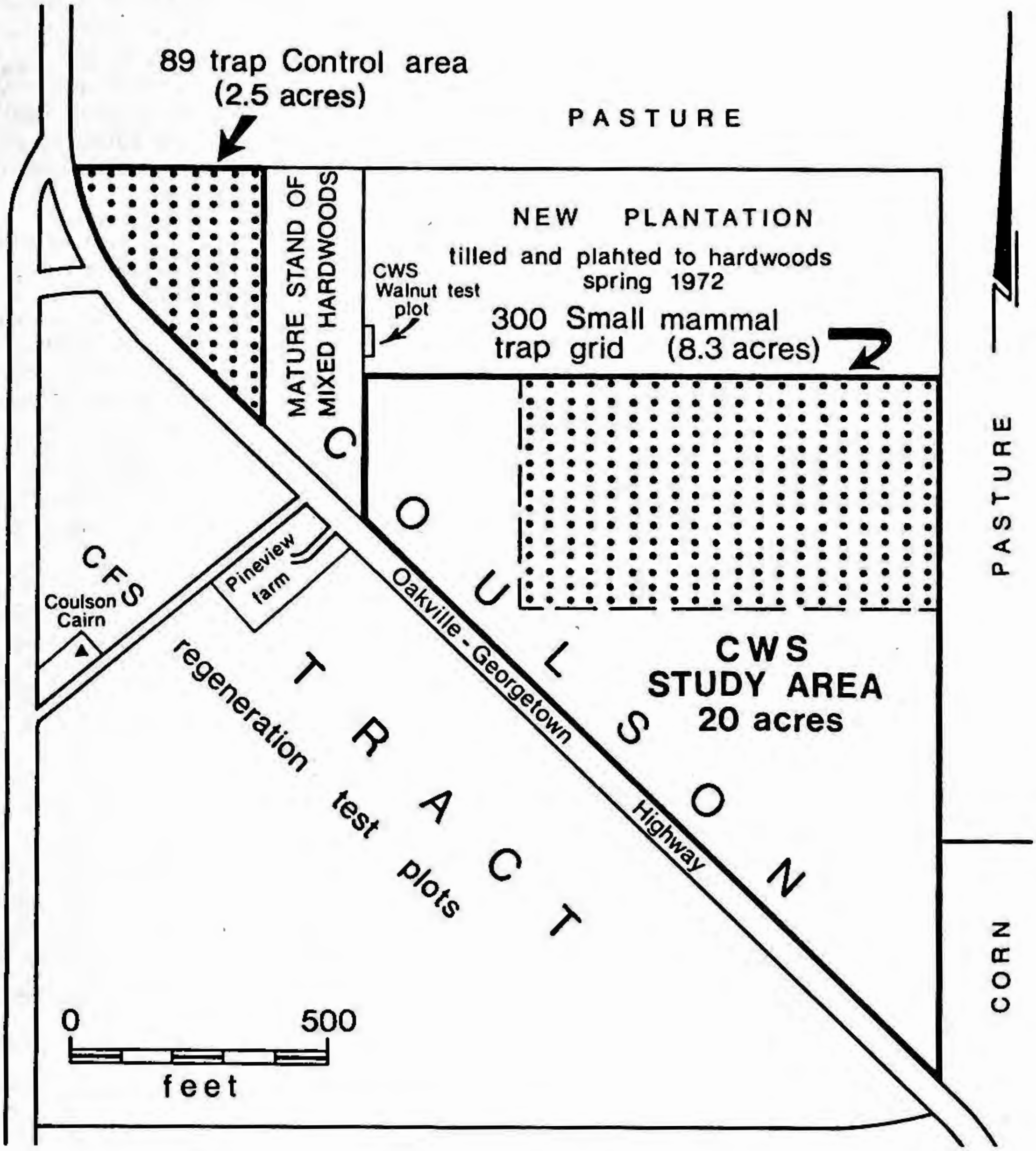

Figure 2. General layout of the Coulson Tract study area showing location of the main 300 trap grid and the 89 trap control grid used in determining small mammal populations existing on the area.

To evaluate the influence of rapid breeding and rate of reinvasion, the small mammal population on the 8.3 acre grid were again live trapped and tagged over a 10 day period in mid September 1972. The small mammal population had increased again from 3.3 to 12.5 animals per acre. A second poisoning program at the 15 pounds of bait per acre rate reduced the population to 4.4 animals per acre by mid October 1972.

Application of Rozol anticoagulant treated grain, therefore, proved to be an effective but temporary means of eliminating harmful small mammals from the plantation study area. Reinvasion of the area from the adjacent hay and pasture fields was even more rapid in late summer than it had been in the spring and could readily negate the effectiveness of the poisoning program. The effectiveness of the broadcast poisoned grain could be reduced in that much of the grain could be lost in the dense vegetation and the poison could be washed off from the grain if heavy rain should occur within a short interval following broadcast application. A means of long-term control of rodent populations was needed if the trees were to be protected from girdling damage during the winter months. The development of such a long-term method of control was the primary aim of Canadian Wildlife Service studies on the Coulson Tract in 1973.

Despite the fact that small mammal populations on the Coulson Tract study area had been virtually wiped out twice during 1972, 10 days of live trapping in mid June 1973 indicated 57.8 animals per acre were present on the area. An exceptionally mild winter, considerable reinvasion from surrounding fields and rapid breeding undoubtedly contributed to this major increase in population. Only three (Microtus) of 227 small mammals tagged on the area during 1972 were recaptured in 1973.

To reduce this high population (98.5 percent of which were Microtus) a new approach to the poisoning program was needed in which poisoned bait could be dispensed to the rodent population over a prolonged period. The need to protect the poisoned bait from inclement weather and thus provide this long-term means of rodent control led to the development and field testing of the Radvanyi poisoned bait feeder station such as shown in Figure 3. The feeder station consists essentially of two 24-inch lengths of 2-inch galvanized metal drain pipes, cut and soldered together to form an inverted "T". The feeder device is supported by being tied to a small wooden stake. The vertical tube holds approximately 28 ounces of poisoned grain. A circular disc lid on the vertical tube serves to shield the grain supply from rain. Mice enter the horizontal tube from either end and consume the grain within. This bait feeder station developed for forest rodents is similar in general shape to one which was designed and used in the Hawaiian Islands for the control of rats in sugar cane.

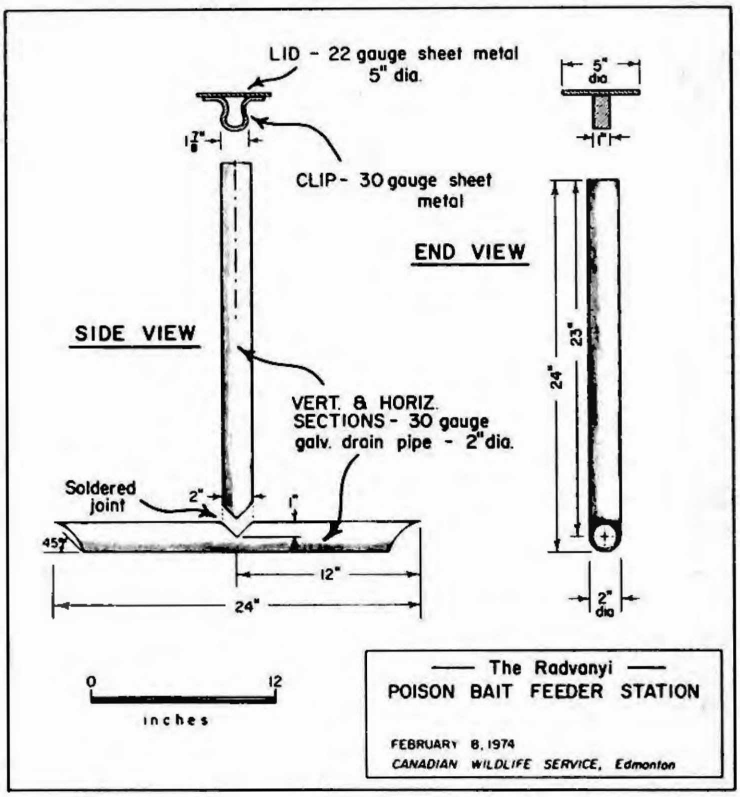

Figure 3. One of 200 Radvanyi poisoned bait feeder stations set up to reduce numbers of harmful small mammals on the Coulson Tract. The vertical tube holds 28 ounces of poisoned grain. Mice enter from either end of the horizontal tube to feed on the grain.

Two hundred Radvanyi feeder stations were set up on the 20 acre study area of the Coulson Tract and baited on June 23. Within 24 hours many of the feeder tubes were being utilized by the rodent population as evidenced by the scattering of grain kernels to the end of the horizontal tubes. Live trapping to assess the effectiveness of the feeder station concept was commenced on July 3 and carried on for a second 10-day period. Within several days a dozen or more dead Microtus were found near feeder stations and the stench of many more dead ones in the grass could be detected as one proceeded from one live trap to another on the grid. By the end of the post-treatment trapping period, the small mammal population had been reduced from 57.8 to 29.3 animals per acre. Of 318 small mammals handled in June prior to introduction of the poisoned bait feeder stations, only 33 were encountered in the post-treatment trapping period. The greatest reduction in Microtus numbers occurred amongst the adult age class possibly as these animals would more likely be able to feed on grain than would juvenile animals. As indicated in Figure 4, whereas 79.6 percent of the animals handled prior to installation of the feeder stations had been adults, only 37.0 percent of animals in the post-treatment period were adults. The percentage of trapped juveniles rose from 12.6 percent (pre-treatment) to 40.7 percent (post-treatment).

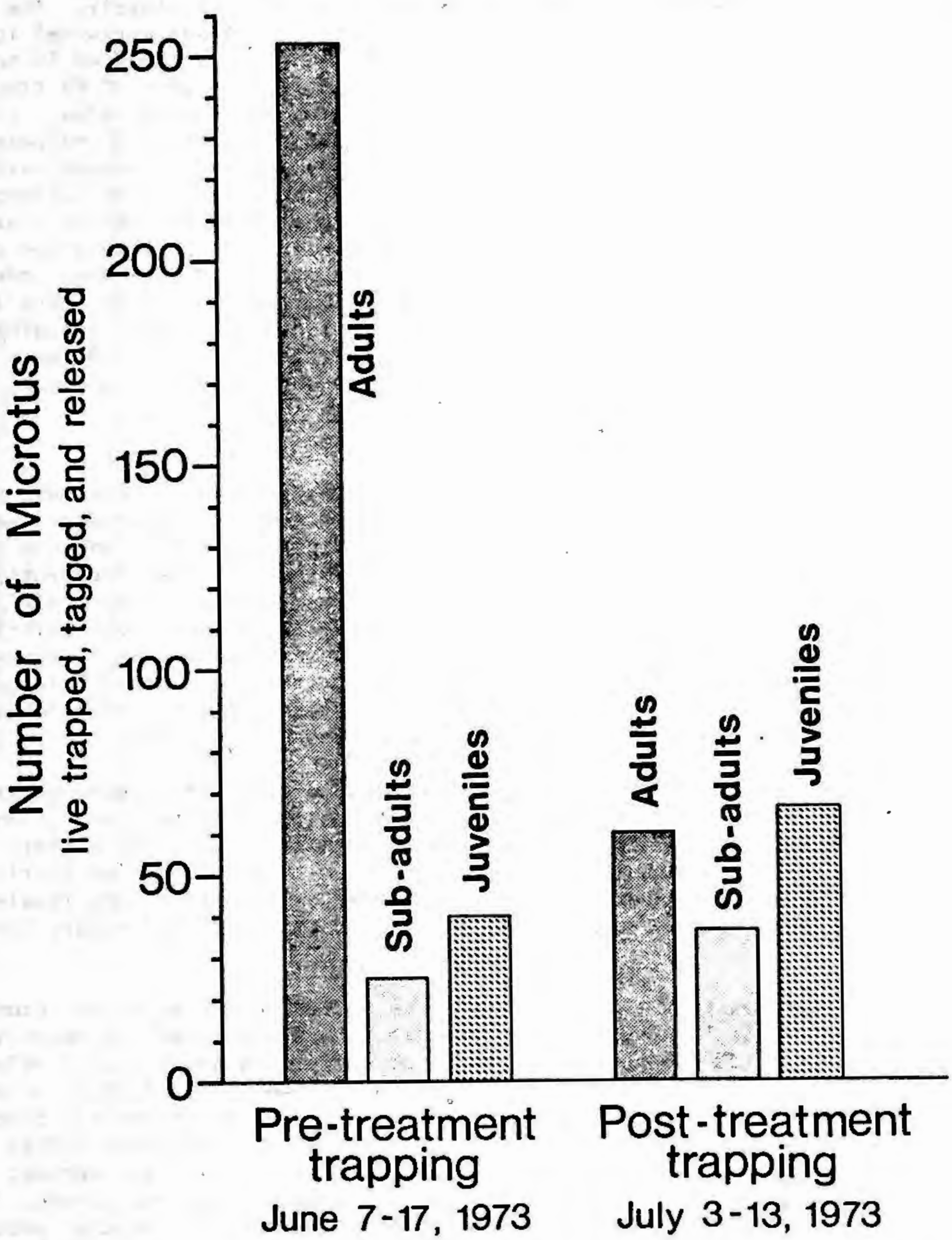

Figure 4. Three age groups of Microtus during pre- and post-treatment period. The poisoned bait feeder stations caused greatest reduction in numbers of adult animals. The juvenile animals probably were too young to feed on the poisoned grain and thus suffered less kills.

Following the July trapping period, the poisoned bait feeder stations were checked, grain added where needed, and allowed to remain functional and unattended throughout the remainder of the summer. Ten days of trapping during September 15-25/73 on the 300 trap grid indicated the small mammal population had been reduced to 2.7 animals per acre. The dramatic decrease in rodent numbers could have resulted from either of two factors, namely 1) either the poisoned bait feeder stations had been extremely effective in not only killing off the resident rodent population but also the invaders which undoubtedly continued to migrate into the depopulated area throughout the summer, or 2) a population crash in small mammal populations had occurred resulting in a coincidental but nonetheless drastically reduced rodent population over the whole countryside.

To test the possibilities of the latter assumption, a second, control study area of the Coulson Tract plantation on which no poisoning or trapping program had been previously carried out was selected as shown in Figure 2. In respect to tree species, date of planting, and vegetation cover, the control area resembled the main study area closely. The two did differ only in that a failure on the part of the department of highway personnel to place a gate into the fence separating the control area from the highway had resulted in no tractor and mower being able to enter the area to reduce the weed cover. A grid of 89 trapping stations were established using the same 40' x 30' spacing on the control area. Live trapping and tagging procedures carried out between September 25 and October 5 indicated a small mammal population of 92.1 animals per acre (Figure 5). Only a stand of mature hardwoods 250 - 300' across separated the control area from the main study area. The hardwood stand appeared to provide an effective barrier against rodent travel between the two areas. The very high population on the control area suggests conclusively that no population crash had occurred and the marked reduction in mammal numbers on the main study area was indeed due to the effectiveness of the poisoned bait feeder stations. The feeder stations were replenished following the trapping program and allowed to remain functional throughout the winter. A check and servicing of the stations is to be made by forestry personnel in December 1973 and March 1974 to assure continued functioning and utilization during winter months.

Implications of Rodent Numbers and an Effective Control

The excessive damages which small mammals can cause to plantation areas have been described amongst others by Siegler (1937), Parker (1941), Littlefield, Schoomaker, and Cook (1946), Staebler, Lauterbach, and Moore (1954), Jokela and Lorenz (1959), and von Althen (1971). A variety of small mammal species are usually involved but most frequently meadow voles, *Microtus*, have been singled out as being the most destructive. They are widespread in distribution and are found in grassy areas throughout North America, particularly in areas of heavy sod. In such habitat, *Microtus* construct numerous tortuous runways along which the animals forage for food. The runways are often littered with short lengths of stems and leaves of vegetation which the mice cut as they feed. Where vegetation and snow cover are sparse, meadow mice construct an underground network of tunnels.

Microtus have a prodigious rate of reproduction. Eadie (1954) maintains under experimental conditions, one female is capable of producing seventeen litters a year. Under natural conditions, five to ten litters are produced and average five young per litter. He considered the gestation period to be about twenty-one days, with a heat period shortly after partuition. By three weeks, the young live an independent existence. Young females may breed at four weeks of age, although males must be five to six weeks old before they mature sexually.

With such rapid reproduction, the numbers of mice occurring per acre can become very large although the population is considered to vary in cycles with peaks at roughly four year intervals following which the numbers decrease abruptly to a condition of relative scarcity (Hoffman, 1958; Chitty, 1960; Marsh, 1962; Krebs, 1966). The factors responsible for the rapid die-off of large numbers of mice have been studied by scientists throughout the world but without agreement as to the single causative agent. Vertrees (1959) suggests the reduction from excessively high numbers does not take place until late spring; thus serious over-winter damage may be inflicted on perennial crops, trees and shrubs. The rise and fall of mouse numbers, while termed "cyclic" is, nevertheless, not regular enough to predict the exact year in which damaging numbers can be expected.

While the actual numbers of mice present in peak populations would vary greatly from one area to another and would be influenced by many biotic factors, estimates of such numbers have ranged equally widely. Eadie suggests an average good habitat may support thirty to sixty mice per acre in mid summer of an average year but that these numbers could be doubled, tripled, or quadrupled during the peak year in the three to four year cycle. Meadow voles were so abundant in the Oregon meadow mouse irruption of 1957-58 (Vertrees, 1959) as to stimulate newspaper accounts of 10,000 mice per acre. Five field studies in the area, however, disclosed no population figure in excess of 800 mice per acre. A half century ago Seton (1929) had estimated meadow mice populations of 10,000 per square mile during peak years. Even this figure may appear conservative in light of our current study.

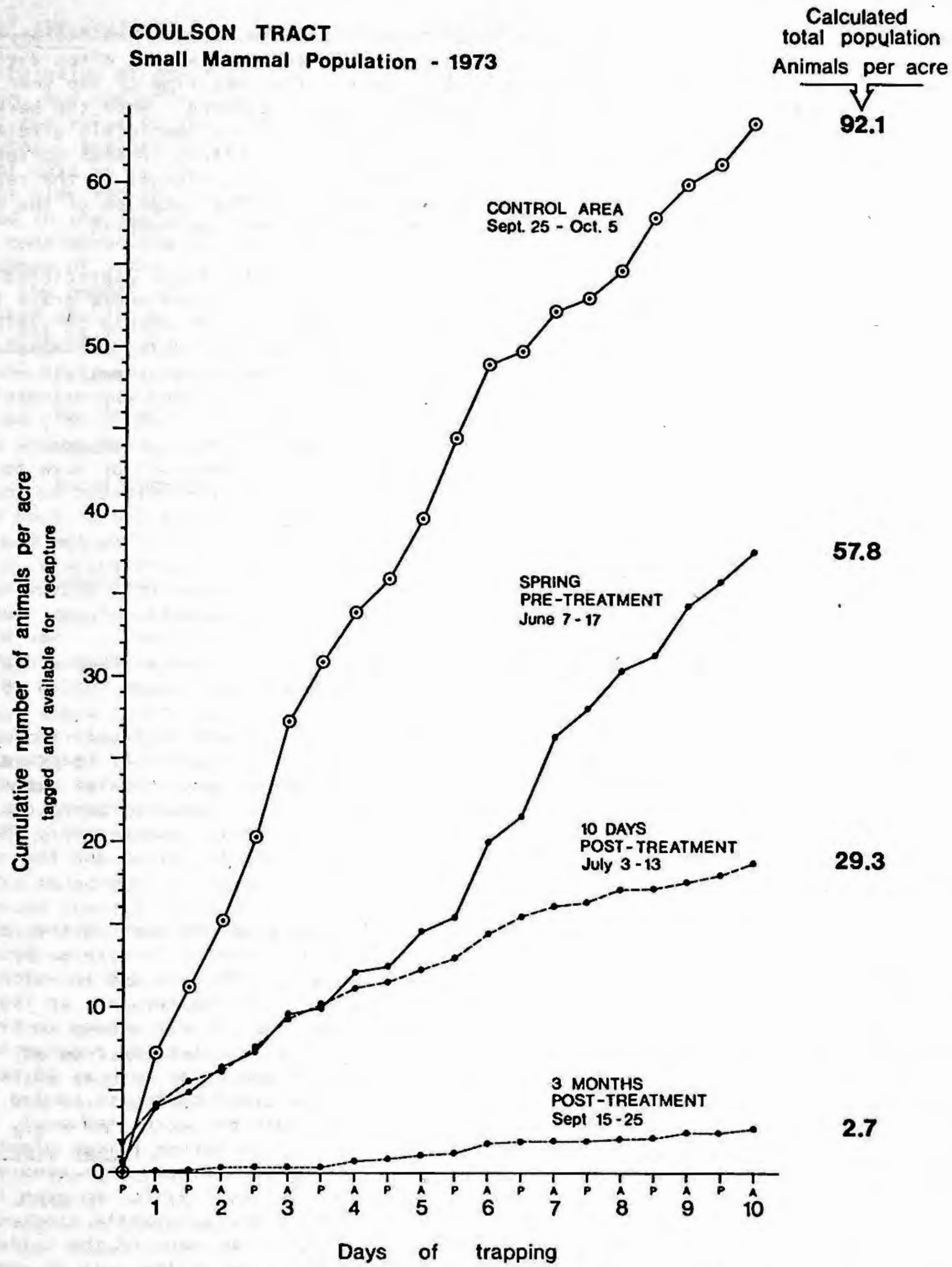

Figure 5. Cumulative number of small mammals tagged and released per acre on the Coulson Tract during 10-day trapping periods pre- and post-poisoning treatment of the study area. Figures at right indicate calculated population levels at end of trapping periods.

The damage perpetrated by these animals can range from a steady unnoticed removal of grass from hayfields and pastures to the dramatic over-winter removal of bark from many fruit trees and plantation seedlings. Eadie calculated 100 mice per acre in a meadow would consume over a ton of green vegetation or the equivalent of one-half ton of dry hay. Bailey (1924) estimated as few as 10 Microtus per acre (a very low population) would consume 11 tons of grass or alfalfa per 100 acres each year (about 5 percent). In a more recent study Rudd (1964) considered 100 mice per acre were capable of consuming 4 percent of the annual production of alfalfa.

One of the most destructive and conspicuous types of damage occurs when Microtus feed upon the inner bark of a variety of tree species. Such damage occurs most often during winter months, but, as noted on the Coulson Tract, may occur at any time of the year. The outer bark of the tree is removed and the underlying cambium devoured. When the bark is removed in a complete ring around the trunk, the tree dies. If not completely girdled, the vigor of the tree is greatly reduced and growth and production suffer. A wide variety of tree species and age groups may be attacked and in plantation areas losses in the realm of 95 percent are not uncommon. The clear, narrow teeth marks and the location of the damage at the base of the trees, indicates the damage is caused by mice, not rabbits.

The implications and impact of large rodent numbers is seldom fully appreciated by farmers. In western Canada where similar rodent problems can occur and where grain is frequently left swathed under the snow, 40 bushel per acre crops can be reduced to yields of only 20 bushels per acre when threshing is completed in the spring. Voles can have destroyed the balance of the crop (Wood, 1947). The same reference indicated scientists working for the United States Department of Agriculture state each vole requires approximately 30 pounds of green vegetation food, eaten or wasted, per year. In other words, only 66 mice of this type destroy one ton of vegetation per year - be this in the form of grassy vegetation, immature grain heads, or as mature grain. If this rate of destruction were to be applied to a square mile of habitat carrying a small mammal population similar to that found on the control area of the Coulson Tract, the small mammal population on such a square mile area would be 58,944 animals and would have the potential of destroying the equivalent of 892 tons of vegetation per year. Even very high densities of big game animals in ideal habitat - say 25 white-tailed deer or 4 moose per square mile, consume only approximately 20 tons of vegetation per species per year (Telfer, 1972). The immensity of the impact of small mammals on the environment is seldom appreciated by the general public. Nor have studies on the Coulson Tract been carried out long enough to determine whether a peak has been reached in the rodent cycle during 1973. Even high numbers may occur during 1974.

Evaluation of the damage caused by small mammal populations are difficult to come by because 1) few accurate data on rodent population surveys are available, 2) inaccuracies in assessment of the damage caused, and 3) reluctance on the part of governmental agencies to release information on how much of the tax payers money has been spent on rodent control measures which have yielded so poor results. On the Coulson Tract, approximately $300 per acre has been spent in past years in attempts to establish that plantation and the results to date have been highly unsatisfactory.

Another area in which small mammals have played a major role has been in the impact they have exerted on regeneration of cutover forest lands - a problem foresters throughout much of North America have tried to solve over more than a half century and in which the poisoned bait feeder stations may have considerable potential in the future. In the decade ending in 1972, 247,000 acres of forest land in Canada have been direct seeded to bring about regeneration (Richardson, 1973). The results of this direct seeding program have been poor - due largely to seed losses to small mammals. In some years, as much as 50 percent of treated coniferous seeds can be destroyed within a few weeks after broadcast sowing even though small mammal populations may be as low as 3 to 5 animals per acre (Radvanyi, 1973). In Alberta, 130,000 acres have been seeded since 1959 with white spruce [Picea glauca (Moench) Voss] and lodgepole pine seeds (Pinus contorta Dougl.). Success has been very poor with 83% of the area having less than 20 percent stocking (Hellum, 1973). An area is termed successfully regenerated only if 80 percent of the test plots are adequately stocked. Non-treated spruce seed costs from $50 to $70 a pound depending on how many of the collecting, extracting, and storage costs are included, and is generally sown at the rate of one pound per acre. The seed supply alone for the Alberta seeding program was thus worth in excess of $4.5 million of which small mammals have taken their ample share. These losses have occurred despite the fact that foresters have treated much of the seed supply with bird repellents, insecticides, fungicides and supposedly rodenticides. Until the forest industry learns to assess and cope with the small mammal problem, forest regeneration endeavours will continue to be a very costly and unproductive procedure.

For the same reasons as mentioned earlier, cost figures on rodent damage on a world-wide basis are not available. One figure mentioned in the U.S.A. estimates a single rat causes $20 damage a year. Of this 25 percent is in the food the animal eats; 75 percent in the spoilage and contamination it causes. In developing countries it is estimated rat populations equal human populations. If these two statistics were applicable to Alberta, rat damage in Alberta would cost $32 million annually.

Cost of the Poisoned Bait Feeder Tube Control Method

The value of any rodent control program must consider both the cost of implementing the program, and the effectiveness of the measures to be taken. These, to be worthwhile must offset the value of the damage which small mammals would cause should no control program be initiated. Because of the short duration of the southern Ontario study to date, and the lack of data as to long-term requirements, no precise cost figures can be presented at the present time for the installation and maintenance of a feeder station control method such as used in the Coulson Tract study. Any cost evaluation would depend directly upon such basic considerations as the number of feeder tubes used per acre, their cost of manufacture, the number of years during which they are used, the current cost of rodenticides and bait grain, the number of animals utilizing the bait, the frequency with which the bait is replenished and labour costs. Initial establishment costs incurred in the current study - on a per acre basis and utilizing 10 feeder stations per acre were as follows:

Feeder tubes - 10 at $1.00 per	$10.00
Oat groats - 12.50/cwt:28 oz. per feeder	2.20
Wooden support stakes	.50
Rozol rodenticide - 16.00/lb to treat grain for 10 feeder tubes once	1.40
Dye	.25
Adhesive	.25
Cost (excluding labour)	$14.60

The feeder stations could cost $5.00 a piece or more if manufactured in a commercial tinsmith shop. Those used in the study were fabricated in a public institution of enforced holidays where hourly wages are not included in the fringe benefits. One man-day is required to treat 500 - 600 pounds of grain using a power-driven cement mixer. Depending upon the spacing of the feeder stations in the field and the mode of delivering the grain to them, one man can service approximately 150 feeder stations a day. Once the feeder stations had been set up, maintenance costs would be approximately 1/3 those quoted above and would be related to the amount of treated grain required to replenish the feeder tubes each time.

The poisoned bait feeder station has proven to be an effective and inexpensive means of year round control of harmful rodent populations. The apparatus has several distinct advantages over other control methods:

1. It works.
2. The structure is simple and has no moving parts to malfunction.
3. It is easy to operate and once installed requires attention only once every three to four months.
4. The darkened tube structure is in itself an attractant to wild mice and serves to lure them to the poisoned grain within.
5. The vertical tube provides gravity feed replenishment of the poisoned bait as the grain is consumed within the horizontal tube.
6. Very important is the fact that the poisoned grain is protected both from spoilage by the elements - thus giving the possibility of long-term control and via the small diameter of the tube, against consumption of the treated grain by animals one would not wish to poison (i.e., birds).
7. The feeder stations can be operated the year round, even when deep snow covers the area. Mice remain active under the snow and having accepted the feeder stations as an ample source of food, are attracted to them and build their tunnel runways to the stations. Some even build their nests within the horizontal tubes. The brightly painted lid of the vertical tube facilitates their relocation in deep snow for mid winter servicing.
8. The feeder stations are lightweight, readily portable and easily moved to new problem areas by unskilled labourers.
9. Being functional the year round, the feeder stations not only kill off resident ro-

dent populations but continue to function effectively to cope with additional populations that invade the protected area from the surrounding fields.

10. Being constructed of galvanized sheet metal and having no moving parts, with normal use each station should last 5 to 10 years thus providing a low per year cost for a very effective method of rodent control.
11. Because of their portability, the feeder stations could be used to control rodent populations in orchards, near stored grain bins, haystacks, barns, in cultivated crops, plantations - wherever rodents congregate and cause considerable damage. They are completely self-sustaining and need never to be re-set with each effective kill.
12. While the feeder stations have been primarily designed to dispense poisoned bait to harmful small mammals, they could just as readily be used as a means of disseminating anti-fertility compounds, or other purposeful ingredients to a select population of animals. The diameter of the horizontal tube precludes utilization of the treated grain by birds or larger beneficial animals such as skunks, coyotes, cats. A slightly larger diameter tube could be of value in rat control programs such as carried out in Alberta.

The conflict between small mammals and man has gone on for centuries. Years ago these small animals, while considered a nuisance, were not regarded as a serious problem. Many agricultural changes have occurred since then which place a greater awareness on the damage these animals can inflict upon man and his crops. Farming practices today yield larger and larger monocultural crops which provide in abundance both food and shelter for small mammals and enhance their numbers. More significant, perhaps, has been the systematic reduction through pesticides and hunting of the avian and mammalian predators - hawks, owls, wolves, coyotes, foxes, weasels, and skunks. Small mammals are the staple diet of such predators and reduction in the numbers of these natural controllers can only result in increased numbers of small mammals. Man has placed a heavy hand on one side of the balance of nature and the corrective weight he is having to bear in order to bring about a tolerable equilibrium is the cost of damages such large numbers of small mammals can inflict upon him. Man has not yet come to appreciate just how high these costs can be.

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